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(54) Method for producing "poly-N-butene oils" from C4-fraction residues.

(57) The method consists in the polymerization of olefins with a prevailing content of 1-butene and cis- and trans-2-butenes in the mixture of hydrocarbons known as rafinate II, which is derived from the C<sub>4</sub>-fractions after separation of 1,3-butadiene and isobutylene, under initiation with boron trifluoride (BF<sub>3</sub>) or alkylaluminium chlorides with the general formulae R<sub>2</sub>AlCl and RAlCl<sub>2</sub> (in which each R represents a C<sub>1</sub> to C<sub>6</sub>-alkyl group) in the presence of hydrogen chloride (HCl), hydrogen fluoride (HF), or organic compounds with a reactive chlorine or fluorine bonded to a tertiary-, benzyl- or allyl-carbon atom, as coinitiators.

The method according to the solution may be carried out in such a way, that rafinate II derived from the production of methyl tert-butyl ether or from the selective polymerization of isobutylene, in which 1-butene present in a concentration at least 20% is polymerized together with cis- and trans-2-butenes present in a concentration of at least 15%, at a temperature of +100°C to -70°C, to form oily products with molar mass  $\overline{M}_n = 300$  to 1200. Preferably the mixture derived as rafinate II from the production of methyl tert-butyl ether is first freed of methanol to the content lower than 300 ppm.

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**Description****Method for producing "Poly-n-butene oils" from C<sub>4</sub>-fraction residues**

The invention pertains to a method for producing "Poly-n-butene oils" from the residue of C<sub>4</sub>-fraction which comes off from the pyrolysis C<sub>4</sub>-fraction after separation of 1,3-butadiene and isobutylene.

The oligomers of alpha- and iso-olefins, produced by the cationic polymerization with AlCl<sub>3</sub>, BF<sub>3</sub> or alkylaluminium halides as initiators, belong to technically important synthetic oils. The polymerization of propylene and higher linear alpha-olefins is carried out mostly without an auxiliary solvent, i.e. in bulk, to oils with molecular mass M<sub>n</sub> = 300 to 1000. The production of these oils employs monomers with a relatively high purity (more than 98%).

On the other hand, low-molecular weight polymers of isobutylene with oily to semisolid consistency are produced not only from the pure monomer, but also by the polymerization in the pyrolysis C<sub>4</sub>-fraction already freed of 1,3-butadiene where isobutylene is present in a high concentration ranging from 30 to 55 wt.-%. This depleted C<sub>4</sub>-fraction, also called rafinate I, contains from C<sub>4</sub>-olefins still n-butenes, which may be polymerized or copolymerized with isobutylene. Considering that isobutylene polymerizes cationically much more readily than n-butenes, products obtained by polymerization of olefins in the depleted C<sub>4</sub>-fraction consist predominantly of polymers of isobutylene and a small amount of its copolymers with n-butenes. These products are produced industrially and are available on market under the name "Polybutenes".

The polymerization of isobutylene in the rafinate I can be performed also entirely selectively without participation of the present n-butenes. A mixture of hydrocarbons falling off in such a polymerization after separation of polyisobutylene contains concentrated n-butenes. Besides the selective polymerization, isobutylene present in the rafinate I is recently mostly processed to the lead-free anti-knock methyl tert-butyl ether (MTBE). Also from this production a hydrocarbon mixture rich in n-butenes comes off and has about the same composition as the residue after selective polymerization of isobutylene, but may contain a low concentration of methanol. The waste mixture of hydrocarbons from both processes is also called "rafinate II" and is characterized by the absence of isobutylene or its low concentration. The waste mixture resulting from the selective polymerization of isobutylene or from the production of MTBE mostly contains 30 to 55 wt.-% 1-butene, about 10 wt.-% cis-2-butene, and 17 wt.-% trans-2-butene. In addition to the said n-butenes it may contain of olefins still a residue of isobutylene, but its concentration is usually not more than 3 wt.-%. n-Butane and isobutane are present in the rafinate II as saturated C<sub>4</sub>-hydrocarbons and mostly do not exceed 30 wt.-%. Wastes of the C<sub>4</sub>-fraction (rafinate II) contain as much as 75% olefins able to polymerize cationically and are, for this reason, a valuable secondary raw material.

While "Polybutenes" are produced by the poly-

merization of isobutylene in the rafinate I already for many years, an industrial production of "Poly-n-butenes" by the direct polymerization of 1-butene with 2-butenes in the rafinate II is not yet known. n-Butenes can be polymerized by aluminium chloride (AlCl<sub>3</sub>), but application of this initiator is connected with certain problems. Because aluminium chloride (AlCl<sub>3</sub>) is not soluble in paraffinic hydrocarbons, its dosing into reaction mixture requires not very suitable auxiliary solvents, as are halogenated or aromatic hydrocarbons. The most suitable among them is ethyl chloride which reasonably dissolves aluminium chloride (AlCl<sub>3</sub>) and is relatively easily removed from the polymerization product as a low-boiling solvent. On the other hand, however, it makes problems because leaves after polymerization in relief gas together with low-boiling non-reactive hydrocarbons, which are above all used as a fuel. If higher-boiling halogenated solvents are used for dosing of aluminium chloride (AlCl<sub>3</sub>), problems arise with their uneasy removal from the reaction product.

Aluminium chloride (AlCl<sub>3</sub>) may be metered into reaction medium also in the form of a liquid complex initiator which does not require auxiliary solvents. The liquid complex is formed by the interaction of aluminium chloride (AlCl<sub>3</sub>) with toluene or other aromatic hydrocarbon with participation of hydrogen chloride (HCl) or alkyl halogenides. Its disadvantage is that it does not dissolve in the rafinate II and is deposited during polymerization as a heavy viscous liquid on the bottom of reactor. For this reason, suitable dispersion of the heterogeneous initiator in reaction medium requires an efficient stirring of the mixture and even then the consumption of initiator with respect to the product is relatively high. If the absence of aromatic compounds in the product is needed, these liquid complexes cannot be used, because their aromatic component cannot be removed from the product in a simple way.

The above mentioned shortcomings are avoided in the method for producing "Poly-n-butene oils" according to this invention.

An object of this invention is a method for producing poly-n-butene oils, which consist in the polymerization of olefins with the prevailing content of 1-butene and cis- and trans-2-butenes in a mixture of hydrocarbons specified as rafinate II, which comes off from the C<sub>4</sub>-fraction after separation of 1,3-butadiene and isobutylene, under initiation with boron trifluoride (BF<sub>3</sub>) or alkylaluminium chloride of the general formula R<sub>2</sub>AlCl or RAICl<sub>2</sub> with C<sub>1</sub> to C<sub>6</sub> alkyls in the presence of hydrogen chloride (HCl), hydrogen fluoride (HF), or organic compounds with reactive chlorine or fluorine bonded on the tertiary-, benzyl- and allyl-carbon atom as coinitiators.

Another feature of the method is that the rafinate II coming off from the production of methyl tert-butyl ether or from the selective polymerization of isobutylene is used in the production where 1-butene is

present in the concentration of at least 20 wt.-% and copolymerized together with cis- and trans-2-butenes present in the concentration of at least 15 wt.-% at temperature +100°C to -70°C to oily products with molecular mass  $M_n = 300$  to 1200.

An important feature is also that the mixture falling off as the rafinate II from the production of methyl tert-butyl ether is beforehand freed of methanol to the value lower than 3000 ppm.

An advantage of the method for producing "Poly-n-butene oils" according to the invention consists in the fact, that the copolymerization of 1-butene with 2-butenes in the rafinate II is carried out in the presence of initiators which are well soluble in the reaction medium. Another advantage is that the used initiators must not be dosed into the reaction medium only as a solution in halogenated or aromatic hydrocarbons, but that they may be purposefully dosed also in paraffinic hydrocarbons or also without auxiliary solvents. Coinitiators can be metered into reaction medium in the same way as initiators individually also in the rafinate II as such, in olefinic hydrocarbons, and also in halogenated (methyl chloride, methylene dichloride, 1,2-dichloroethane, and others) or aromatic solvents (toluene, benzene, xylene, and others).

Anhydrous hydrogen fluoride (HF), tert-butyl fluoride and benzyl fluoride proved as most suitable coinitiators in the polymerization of n-butenes in rafinate II initiated with boron trifluoride, whereas the best coinitiation effect was observed in the polymerization initiated with alkylaluminium chlorides with anhydrous hydrogen chloride, tert-butyl chloride 2-chlor-2,4,4-trimethylpentan, benzyl chloride, methylallyl chloride and cumyl chloride. However, also other organic compounds with reactive halogen bonded in their molecule to tertiary or allyl carbon atom and compounds with a chloromethyl group on aromatic ring may be used as efficient coinitiators.

Because auxiliary halogenated or aromatic solvents need not be used for initiator dosing in the polymerization of 1-butene with 2-butenes in rafinate II initiated with boron trifluoride or alkylaluminium chlorides, the problems with utilization of hydrocarbons present in the relief gas after polymerization are avoided. If the initiator is dosed in paraffinic hydrocarbons, the oils obtained are not depreciated even with a smallest amount of aromatic hydrocarbons.

The composition of residual C<sub>4</sub>-fraction coming off as the rafinate II from the production of MTBE or from the selective polymerization of isobutylene may vary within broader limits depending on the way of processing and origin of the pyrolysis fraction. Because the polymerization rate, molar mass of the obtained product and consumption of the initiator depend on the concentration of present n-butenes, it is useful to produce poly-n-butene oil from the residual C<sub>4</sub>-fraction containing at least 35 wt.-% of n-butenes.

The higher is the concentration of n-butenes in rafinate, the easier proceeds their polymerization and the consumption of initiator on the product decreases. Considering that the mixture of hydrocarbons, falling off from the production of methyl

tert-butyl ether, contains as much as 4% methanol which is the catalytic poison, the rafinate II has to be washed prior to polymerization, advantageously with water, in order to reduce the content of methanol to the value of 3000 ppm or less. On the other hand, the residual C<sub>4</sub>-fraction coming off from the selective polymerization of isobutylene in rafinate I is usually so pure that it does not need additional refinement and drying for the polymerization of present n-butenes. The rate of polymerization and conversion attained may be controlled by gradual dosing of initiators and coinitiators. It is expedient to carry out the polymerization in the way that first the coinitiator is added into reaction mixture in a sufficient amount and the polymerization rate and attained conversion are then controlled by gradual addition of the initiator. The polymerization can be carried out up to the conversion of 100% calculated on the olefins present.

The reaction mixture after polymerization is worked out in the common way. The best way is to remove the main part of low-boiling fractions by heating to 100°C and to wash the crude product with water or lime milk in order to remove the residues of catalyst. The oily layer is then refined with bleaching earth for oils and hot filtered through a pressure filter. Lighter fractions are removed by distillation while heated up to 140°C or, if desirable, also higher at pressure 0.1 mm Hg. Colourless or light yellow oils are obtained in this way, the composition of which corresponds mainly to co-oligomers of 1-butene with 2-butenes.

Poly-n-butene oils made according to the invention contain in the polymeric chain an olefinic double bond which exhibits an increased reactivity. Their low polydispersity of molar masses  $M_w/M_n = 1.4$ , resistance of oils to thermal oxidation, low solidification temperature, low volatility, and the fact that they do not leave carbonization residues after combustion or at heat loading are also important. For this reason, these oils have a broad technical use and may be applied also in the cases where commercially available low-molecular weight polyisobutylenes and "Polybutenes" have been used, e.g. after reaction with maleic anhydride for the production of ash-less dispersing agents, as lubrication oils for two-stroke spark-ignition engines, oils for the processing of metallurgical materials by rolling and drawing, in leather and rubber industry, and for hydrophobization of insulating materials. Their hydrogenation may provide high-quality transformer oil, electroinsulation and cable oils, and nontoxic cosmetic oils and white oils.

For the detailed illustration of the invention, the preparation of poly-n-butene oils is further described in several examples which, however, do not limit the scope of invention by any means.

The polymerizations were carried out either in a glass pressure reactor with volume of 60 ml cooled from outside or in a stainless-steel reactor with volume of 1000 ml. Both reactors were furnished with a magnetic stirrer and a valve for feeding the reactor and dosing of initiator and coinitiator. Temperature of the reaction mixture was detected with a thermocouple and recorded with a line

recorder. The polymerization course was controlled by the gradual dosing of initiator so that the required temperature in reactor was maintained with accuracy  $\pm 5^\circ\text{C}$ .

Poly-n-butene oil was prepared either from the residual C<sub>4</sub>-fraction (rafinate II), which was obtained as relief gas after polymerization of isobutylene in rafinate I without any refinement and drying, or from the residual C<sub>4</sub>-fraction falling off as rafinate II from the production of MTBE, which was washed 3times with water in order to remove methanol and dried in liquid state over solid KOH in a pressure bottle. The mixture after rafination had the following composition: 41.1 wt.-% 1-butene, 15.1 wt.-% trans-2-butene, 9.7 wt.-% cis-2-butene, 2.2 wt.-% isobutylene, 24.6 wt.-% n-butane, 6.4 wt.-% isobutane, and 0.6 wt.-% propane. The content of methanol was always lower than 3000 ppm and the concentration of methyl-tert.butyl ether was also lower than 0,3 wt.-%.

#### Example 1

A glass reactor with volume 60 ml was charged with 25 g rafinate II, which originated from the production of MTBE, and 0.015 g anhydrous hydrogen chloride (HCl) in gaseous state was added at  $-20^\circ\text{C}$ . By gradual addition of the solution of ethylaluminium dichloride in heptane in small portions, the strongly exothermic polymerization was carried out in such a way, that temperature of the cooled and stirred reaction mixture did not increase after separate doses of initiator above  $-15^\circ\text{C}$ . The polymerization was stopped after 30 min by addition of alcohol, volatile fractions were removed by heating the reaction mixture to  $100^\circ\text{C}$  at 10 mm Hg, and the product was filtered under pressure after addition of 0.2 g bleaching earth at  $80^\circ\text{C}$ . The slightly yellowish oil with number average molar mass  $M_n = 690$  was obtained. The total consumption of ethylaluminium dichloride was 0.47 wt.-% on the product at the conversion of 94.1% calculated on the present olefins.

#### Example 2

A stainless-steel reactor with volume 1000 ml was charged with 450 g residual C<sub>4</sub>-fraction (rafinate II) falling off from the production of MTBE, which was freed of methanol by washing with water and dried over KOH. After addition of 0.25 g gaseous hydrogen chloride (HCl) into reaction mixture at  $60^\circ\text{C}$ , the polymerization was carried out by gradual addition of liquid ethylaluminium dichloride under vigorous stirring. During polymerization, the temperature in cooled reactor was maintained between  $60^\circ\text{C}$  and  $70^\circ\text{C}$ . When a temperature increase have not been observed after the last addition of initiator, the reaction mixture was cooled to  $+20^\circ\text{C}$  and washed with lime milk. The hydrocarbon layer was separated, mixed with bleaching earth and filtered by pressure. Low-boiling hydrocarbons and volatile fractions were removed by heating to  $100^\circ\text{C}$  at 10 mm Hg and oil with molar mass  $M_n = 490$  (determined by VPO) was obtained. The consumption of initiator on the product was 0.44 wt.-% at the attained conversion of 97.1% calculated on olefins in the initial mixture.

#### Example 3

n-Butenes in the rafinate II from the production of MTBE were polymerized at  $-70^\circ\text{C}$  by gaseous boron trifluoride (BF<sub>3</sub>) under coinitiation with anhydrous hydrogen fluoride (HF). A glass reactor cooled to the chosen temperature was charged with 25 g rafinate II and 0.01 g gaseous hydrogen fluoride was introduced. The polymerization proceeded by gradual introducing of boron trifluoride in the region  $\pm 5^\circ\text{C}$  around the chosen temperature. The reaction mixture after completed polymerization was heated to  $+20^\circ\text{C}$ , partially degased and 0.2 g powdered calcium oxide (CaO) and 0.1 g water was added. After thorough mixing, the mixture was filtered and the crude product was freed of volatile fractions by heating to  $100^\circ\text{C}$  at 10 mm Hg. The resulting colourless oil had molar mass  $M_n = 320$  at the consumption of 0.38 wt.-% boron trifluoride (BF<sub>3</sub>) on the product. The yield of oil was 93.6 wt.-% related to the present n-butenes.

#### Example 4

Into 450 g rafinate II from the production of MTBE, 0.5 g tert-butyl chloride was added and then ethylaluminium dichloride in hexane solution was metered in small doses at  $-40^\circ\text{C}$  under continuous stirring of the reaction mixture. The polymerization was stopped after 50 minutes by addition of ethanol, the content of reactor was heated to  $+30^\circ\text{C}$  and washed with water. After draining the lower aqueous layer, bleaching earth was added into reactor, the crude product was vigorously stirred and then filtered under pressure. Volatile and low-boiling fractions were removed from the product by gradual heating to  $140^\circ\text{C}$  at 0.1 mm Hg. The obtained lightly yellowish oil had number average molar mass  $M_n = 1120$  at the yield of 87% calculated on present olefins. The consumption of ethylaluminium dichloride on product was 0.77 wt.-%.

#### Example 5

The polymerization of n-butenes in rafinate II was carried out at  $90\text{--}97^\circ\text{C}$  under initiation with ethylaluminium sesquichloride added into the reaction mixture in the liquid state without auxiliary solvent. Other conditions of the procedure were the same as in example 2. The obtained product had molar mass  $M_n = 320$  and the consumption of initiator on the product was 0.55 wt.-% at the attained conversion of 96.2%.

#### Example 6

The polymerization of n-butene in the rafinate II from the production of MTBE was carried out at  $-20^\circ\text{C}$  under initiation with boron trifluoride (BF<sub>3</sub>) and coinitiation with benzyl fluoride. A pressure glass reactor was charged with 25 g rafinate and 0.05 g coinitiator was added. Then gaseous boron trifluoride was gradually added under continuous stirring and cooling so that temperature of the mixture was kept between  $-20^\circ\text{C}$  and  $-15^\circ\text{C}$ . The reaction was stopped after 30 min, the reaction mixture was washed with water, and volatile fractions were evaporated at  $100^\circ\text{C}$  and 10 mm Hg

giving the colourless product with number average molar mass  $\bar{M}_n = 580$ . The consumption of initiator on the produced oil was 0.35 wt.-%.

The same result was obtained if the polymerization was carried out under analogous conditions with tert-butyl fluoride instead of benzyl fluoride as a coinitiator.

#### Example 7

n-Butenes were polymerized in the residual C<sub>4</sub>-fraction, in this case also specified as rafinate II, which was obtained as relief gas after selective polymerization of isobutylene in the C<sub>4</sub>-fraction freed only of 1,3-butadiene, i.e. in the rafinate I, which contained 45 wt.-% isobutylene, and was assigned for the production of MTBE.

Relief gas obtained after selective polymerization of isobutylene in the rafinate I has the following composition: 30.90 wt.-% butane and isobutane, 42.30 wt.-% 1-butene, and 26.80 wt.-% cis-2-butene and trans-2-butene. This mixture (400 g) was polymerized without further purification and drying at 60°C under initiation with ethylaluminium dichloride added into the reaction mixture as heptane solution. Methylchloride was used as a coinitiator which was gradually added without an auxiliary solvent. The polymerization was stopped after 60 min and the product was worked out as in example 2.

The polymerization of present n-butenes occurred in the yield of 94.3% and the obtained oil had molar mass  $\bar{M}_n = 540$ ; the consumption of initiator was 0.55 wt.-% and of coinitiator 0.4 wt.-% calculated on the product.

#### Example 8

Poly n-butene oil was made from the rafinate II, which was obtained as relief gas from the polymerization of isobutylene in rafinate I in which besides isobutylene also n-butenes were polymerized in part.

The obtained relief gas consisted of 61.3 wt.-% butane and isobutane, 23.2 wt.-% 1-butene and 15.4 wt.-% 2-butenes. The polymerization was carried out at 60°C under initiation with diisobutylaluminium chloride, which was gradually added in small portions without auxiliary solvent into the reaction mixture containing the beforehand added anhydrous hydrogen chloride in the amount of 0.4 g. The polymerization was stopped after 60 min and the reaction mixture was worked out by the procedure described in example 2. The consumption of diisobutylaluminium chloride was 0.61 wt.-% on the product at the attained conversion of 91.3%. The obtained oil had molar mass  $\bar{M}_n = 470$  determined by VPO. The polydispersity measured by GPC was  $M_w/M_n = 1.18$ .

#### Example 9

The polymerization of n-butenes in the rafinate II coming off from the production of MTBE was carried out as in example 1 with the distinction that diethylaluminium chloride was used instead of ethylaluminium dichloride as an initiator, which was dosed into the reaction mixture in liquid state without auxiliary solvent. Anhydrous hydrogen

chloride (HCl) was added in the beginning of polymerization in the amount of 0.03 g. The polymerization was maintained at temperature around -20°C and stopped after 30 min at the conversion of 85.1% calculated on the present olefins. The consumption of initiator was 0.46 wt.-% on the product. The obtained oil had a light yellow colour and molar mass  $\bar{M}_n = 620$  with polydispersity  $M_w/M_n = 1.4$ .

#### Example 10

n-Butenes were polymerized in the rafinate II at -20°C using methylaluminium dichloride as an initiator, which was added into the reaction mixture as a solution in toluene, whereas the solution of benzyl chloride was gradually added as a coinitiator. The total benzyl chloride added into 25 g rafinate amounted to 0.1 g and then the polymerization was stopped. The product was isolated from reaction mixture giving oil with molar mass  $\bar{M}_n = 610$ ; the conversion reached during 30 min of polymerization was 85.1% and the consumption of initiator was 0.61 wt.-%.

#### Example 11

n-Butenes were polymerized as in example 1 with the distinction that the initiation occurred by gradual addition of the solution of hexylaluminium dichloride and hydrogen chloride at +30°C. The reaction was stopped after 30 min and isolation provided light yellow oil with molar mass  $\bar{M}_n = 510$  at the attained conversion of 75.3 wt.-%. The consumption of initiator on product was 0.51 wt.-%.

#### Claims

1. A method for producing "Poly-n-butene oils", wherein olefins with a prevailing content of 1-butene and cis-and trans-2-butene, present in the mixture of hydrocarbons, known as rafinate II, which is derived from the C<sub>4</sub>-fraction after separation of 1,3-butadiene and isobutylene, are polymerized under initiation with boron trifluoride (BF<sub>3</sub>) or alkylaluminium chlorides with general formulae R<sub>2</sub>AlCl and RAICl<sub>2</sub> (in which each R represents a C<sub>1</sub> to C<sub>6</sub> alkyl group) in the presence of hydrogen chloride (HCl), hydrogen fluoride (HF), or organic compounds with a reactive chlorine or fluorine bonded to a tertiary-, benzyl- or allyl-carbon atom, as coinitiators.
2. A method of production according to claim 1, wherein the rafinate II derived from the production of methyl tert-butyl ether or from the selective polymerization of isobutylene is used, in which 1-butene present in a concentration of at least 20 wt.-% is polymerized together with cis- and trans-2-butenes present in a concentration of at least 15 wt.-%, at a temperature of +100°C to -70°C, to form oily products with molar mass  $\bar{M}_n = 300$  to 1200.
3. A method according to claim 1 or 2, wherein the mixture obtained as the rafinate II from the production of methyl tert-butyl ether is beforehand freed of methanol to a content lower than 3000 ppm.